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MELBOURNE, VICTORIA

Flight Mechanics Technical Memorandum 415

PERIPHERY CAMERA SYSTEM

by

F. Pritchard

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SUMMARY

This paper describes a periphery camera system that produces a "flat plane" photograph of the external curved surface of a cylinder.

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PERIPHERY CAMERA SYSTEM

1. INTRODUCTION

The ARL Combustion Group requested the Photographic Section to photograph a TF30 engine flame tube (Fig. 1) in support of Task 86/036. The photograph was to show the complete external surface of the cylindrical flame tube as a flat plane (i.e. a rolled out flat view).

The technique of "Periphery Photography" was chosen whereby photographs are obtained by rotating the flame tube in front of a camera fitted with a movable film back.

For this particular task existing equipment that was used to photograph a flame tube 630 mm in height by 140 mm in diameter was modified. The new flame tube measured 312mm in height by 170mm in diameter. This required new calculations to locate the camera assembly, extension guide rails, pulleys and switches.

2. DESCRIPTION OF EQUIPMENT

2.1 Camera

De Vere 102 mm x 127 mm (4" x 5") format bellows type with a lens panel and focussing back (both adjustable) mounted on a squared section monorail with an adjustable locking head. (Fig.2).

2.2 Lens and Shutter

Tessar f 4.5, 150 mm focal length lens with a Compur shutter and a 'T' time setting. Aperture range f 4.5 to f 32.

2.3 Film Holder

A specially designed wooden film back (Fig.3) allows a normal 102 mm x 127 mm film holder to slide across a slot in line with the optical axis. The film holder is lubricated with Bee's wax to assist a smooth motion.

2.4 Shutter Solenoid

The Compur shutter is mechanically coupled to a solenoid attached to the lens panel. The solenoid is energised from a 6 volt battery power supply. Two cams attached to the bottom of the film holder carrier activate a microswitch connected to the shutter solenoid thus opening the shutter at the beginning and closing the shutter at the end of the film holder travel.

2.5 Turntable

The turntable which supports the flame tube consists of two brass discs separated by a ball bearing located in an indent at the disc centres. The lower disc attaches to the output shaft of the gear base (Fig.4) and the upper disc provides the base for the flame tube. Adjustable screws enable the upper disc to be accurately adjusted so that the front surface of the flame tube remains parallel to the film plane and on the optical axis during the complete revolution of the flame tube.

2.6 Motor

A 240V A.C. synchronous motor drives a gear train which rotates the turntable one revolution in twelve seconds (Fig.4).

2.7 Cable Drive

Piano wire, wound around the turntable shaft and a series of pulleys is attached to the opposite ends of the film back holder. A dampening spring forms part of the drive system to minimise initial inertia shock of movement of the travelling film back.

2.8 System Assembly

The system is assembled on a frame (Fig.5), constructed from 25 mm thick wooden sheet, 355 mm wide by 1530 mm in length and 170 mm in height. The turntable, pulleys and camera (via a camera mount) are attached to a platform on top of the frame. The motor is located under the platform directly beneath the turntable. A switch controlling the power to the shutter solenoid and film back carrier microswitch is located under the camera on the platform. The 6 volt battery and the A.C. motor power switch are readily accessible under the platform at the rear of the frame.

2.9 Illumination

A tripod mounted Quartz Iodine Lamp (3200^{O}K) is used to illuminate the flame tube. The tripod is positioned slightly to the side of the platform and in line with the camera.

3. PRINCIPLE OF OPERATION

The flame tube was accurately aligned on the rotating turntable and fine tuned vertically by using the adjusting screws on the turntable (Fig.4).

The camera was then aligned with the vertical axis of the flame tube. The camera is fitted with a film back holder that moves laterally across the film plane. The lens projects the image of the flame tube on to the film in the camera back holder through a narrow slit (Fig.3.) which ensures that only that part of the flame tube directly facing the lens axis is recorded at any instant. Both the tuntable and film holder are mechanically coupled, by the wire cable, such that when the film has travelled its full distance, the flame tube will have completed one revolution. The result is a flat plane photograph of the entire circumference of the flame tube. (Fig.8).

4. CALCULATIONS

4.1 Magnification and Distances

Film area available is 120 mm x 90 mm in vertical format, but the back frame construction reduces the width available to 80 mm maximum allowing for a slight overlap.

Diameter of flame tube	170 mm
Height of flame tube	312 mm

Hence:

Circumference of flame tube (Π d)	534 mm
Image width of flame tube Circumference	80 mm

The ratio of the image width to the object circumference gives the desired optical magnification M

Hence:

$$M = \frac{80}{534} \qquad (1)$$

Using optical formula (Ref.1)

$$M = \frac{v}{u} \qquad (2)$$

Where:

M is magnification
v is image distance to lens
u is object distance to lens

Substituting M from Equation (1) into Equation (2) gives the ratio of distance between the image and the object

$$M = \frac{80}{534} = \frac{1}{6.68} = \frac{v}{u}$$

$$u = 6.68v \qquad (3)$$

Using lens formula (Ref.1)

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v} \qquad (4)$$

Where:

f is focal length
u is object distance to lens
v is image distance to lens

The absolute distances are obtained by substituting u from Equation (3) into Equation (4) with f = 150 mm

Therefore:

$$\frac{1}{150} = \frac{1}{6.68v} + \frac{1}{v} = \frac{1 + 6.68}{6.68v} = \frac{7.68}{6.68v}$$

$$6.68v = 1152$$

$$v = 172.5$$

Substituting into eqn 3 gives

$u = 1152$

Hence the optical design values become -

Object distance 1152 mm
Image distance 172.5 mm

The flatplane photograph Fig. 6 was obtained with the measured distance from the front centre strip of the flame tube to the lens set to 1152 mm and the distance from the lens to the focal plane adjusted to approx 172.5 mm. The small variation between measured and calculated distance occurred because the nodal points of the lens are not at the physical surface of the lens to where measurements were taken.

4.2 Diameter of Turntable Drive Shaft

Since one revolution of the turntable shaft corresponds to the wire cable having moved 80 mm then the required diameter of the turntable shaft which carries the cable, needs to be:

$$\frac{80}{\Pi} = 25.45 \text{ mm}$$

The turntable shaft was made from 25.4 mm (1 inch) diameter brass rod.

4.3 Effective Time Exposure

Using a conveniently available gear train between the motor and the turntable resulted in one revolution of the turntable in 12 seconds. Since velocity is distance divided by time then the film velocity (S) becomes:

$$S = \frac{80}{12} = \quad 6.7 \text{ mm/second}$$

The measured width of the slit is 1 mm giving an effective time exposure of $\frac{1}{6.7}$ seconds or 0.15 sec.

5. EXPOSURE CONSIDERATIONS

Exposure of the film is determined by the velocity at which the film passes the slit, the intensity of the light and the film speed (ASA value). The aperture is also dependent on these three considerations. Vericolor film type L, 100 ASA balanced for 3200^{O}K was chosen and lighting is provided by a Quartz Iodine Lamp 3200^{O}K. In addition, this film requires exposures of longer than 1/10th of a second which met our effective exposure consideration. The lens aperture is not critical, however, a smaller aperture provides greater depth of field and so minimised focus problems with indentations and protrusions of the flame tube.

A Gossen Lunasix light meter gave a light reading of 16 (4800lux). Reading off the scale at 1/7th sec indicated that an aperture of between f11-16 was needed.

6. OPERATING INSTRUCTIONS

6.1 Fit an aluminium disc with centred hole to bottom of flame tube and attach tube to turntable by a locking bolt.

6.2 Ensure that the flame tube is vertical by using a clinometer and the adjustment screws in turntable assembly.

6.3 Using the clinometer, check that the camera is level and that the lens panel and camera back are vertical. The flame tube, lens panel and camera back should now be parallel.

6.4 Loosen the locking screw on turntable shaft and rotate the flame tube to 'start line' then re-lock.

6.5 Check that film back holder is now at the start (extreme right) position.

6.6 Place lamp in position. Check meter reading to give a light value of 16 (4800 lux). If necessary, move lamp to obtain this figure.

6.7 Set lens aperture to between f11 and f16.

6.8 Position shutter setting to 'T' (Time) and cock.

6.9 Place film holder (loaded with Vericolor L, 100 ASA film) in film holder back.

6.10 Remove sheath from film holder.

6.11 Switch on power supply from battery to shutter solenoid and microswitch. Check that the green indicator lamp is on.

6.12 Switch on the A.C. power supply to the A.C. motor and the equipment should commence operation.

6.13 Observe that the film holder moves smoothly across the back whilst the flame tube is rotating.

6.14 When the equipment has completed the cycle, switch off motor, battery and lighting.

6.15 Replace film sheath and remove film holder.

7. CONCLUSION

The peripheral camera is capable of producing good quality photographs of the external surface of a cylinder. With modification, the interior surface of an open ended cylinder might also be accessible to the camera.

Indentation and protrusions on the cylinder surface represent areas that have different effective diameters compared with the cylinder diameter. Consequently, the local magnification, focus and exposure will vary. With suitable design these effects are able to be minimised.

ACKNOWLEDGEMENTS

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REFERENCE

Applied Photography Arnold,C.R., Rolls, P.J. and Stewart, J.C.J. 1971 Focal Press London.

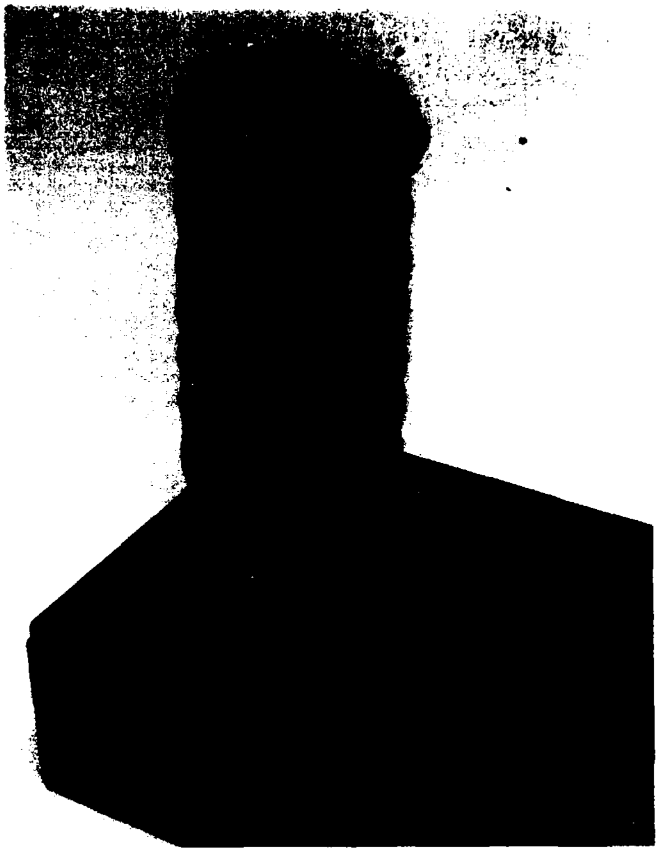

FIG. 1. TF30 ENGINE FLAME TUBE

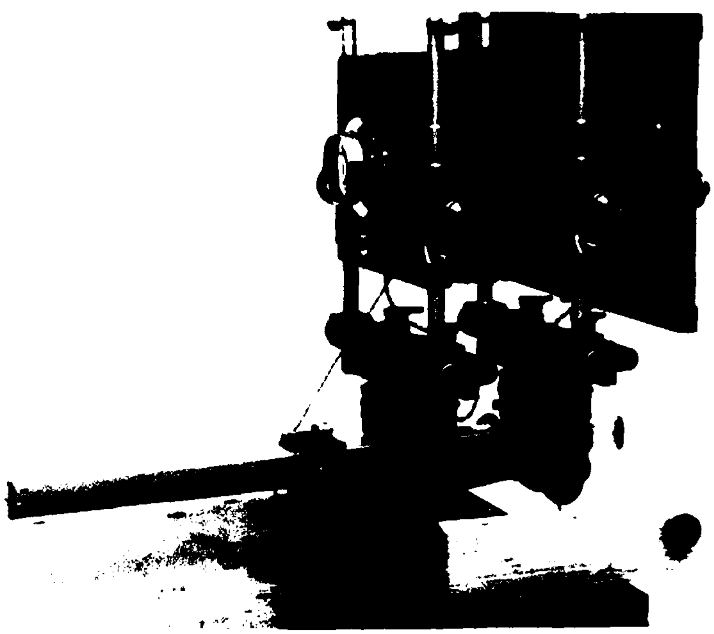

FIG. 2. CAMERA AND MOUNT

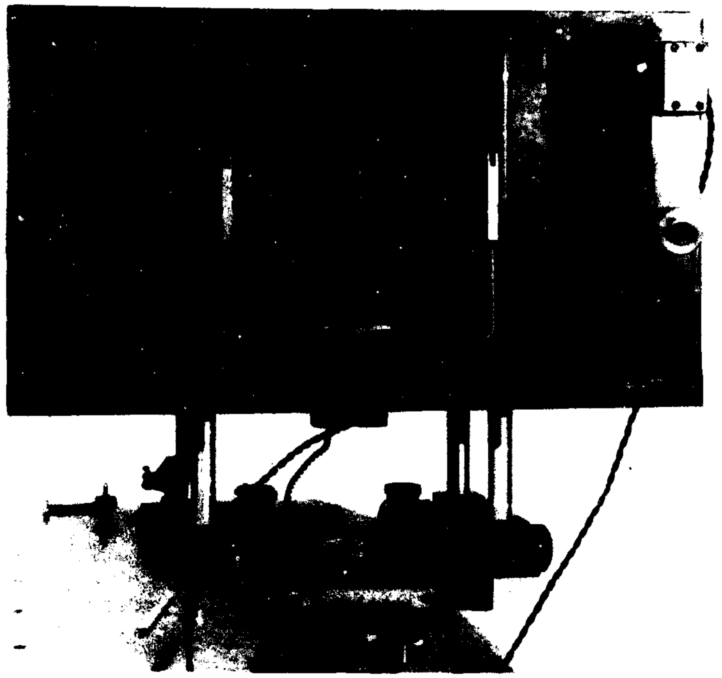

FIG. 3. SPECIALLY DESIGNED WOODEN FILM BACK

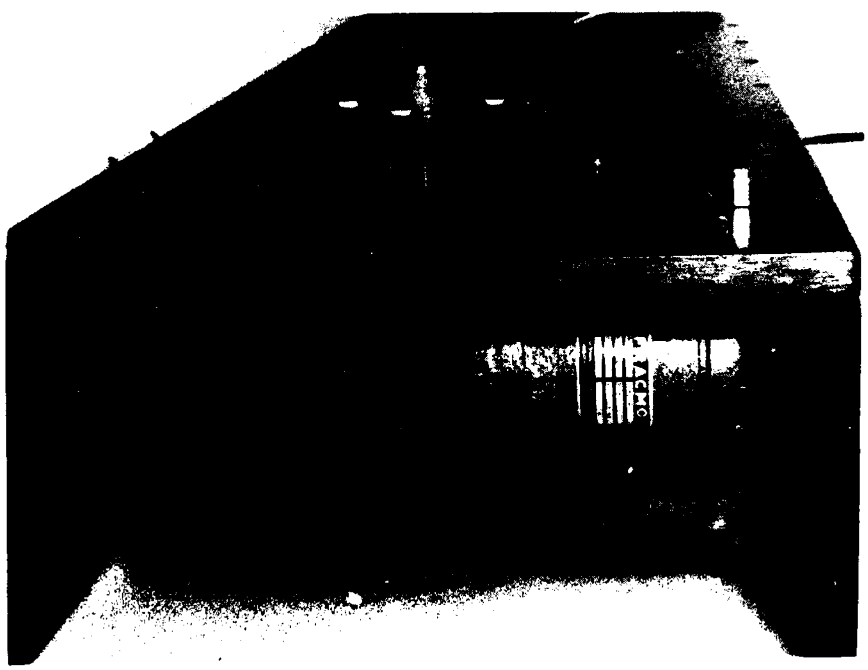

FIG. 4. MOTOR AND GEAR BOX DRIVE TO TURNTABLE

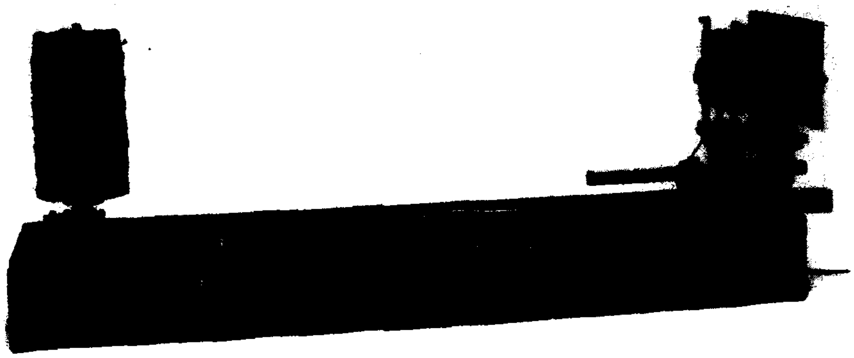

FIG. 5. COMPLETE SYSTEM ASSEMBLY

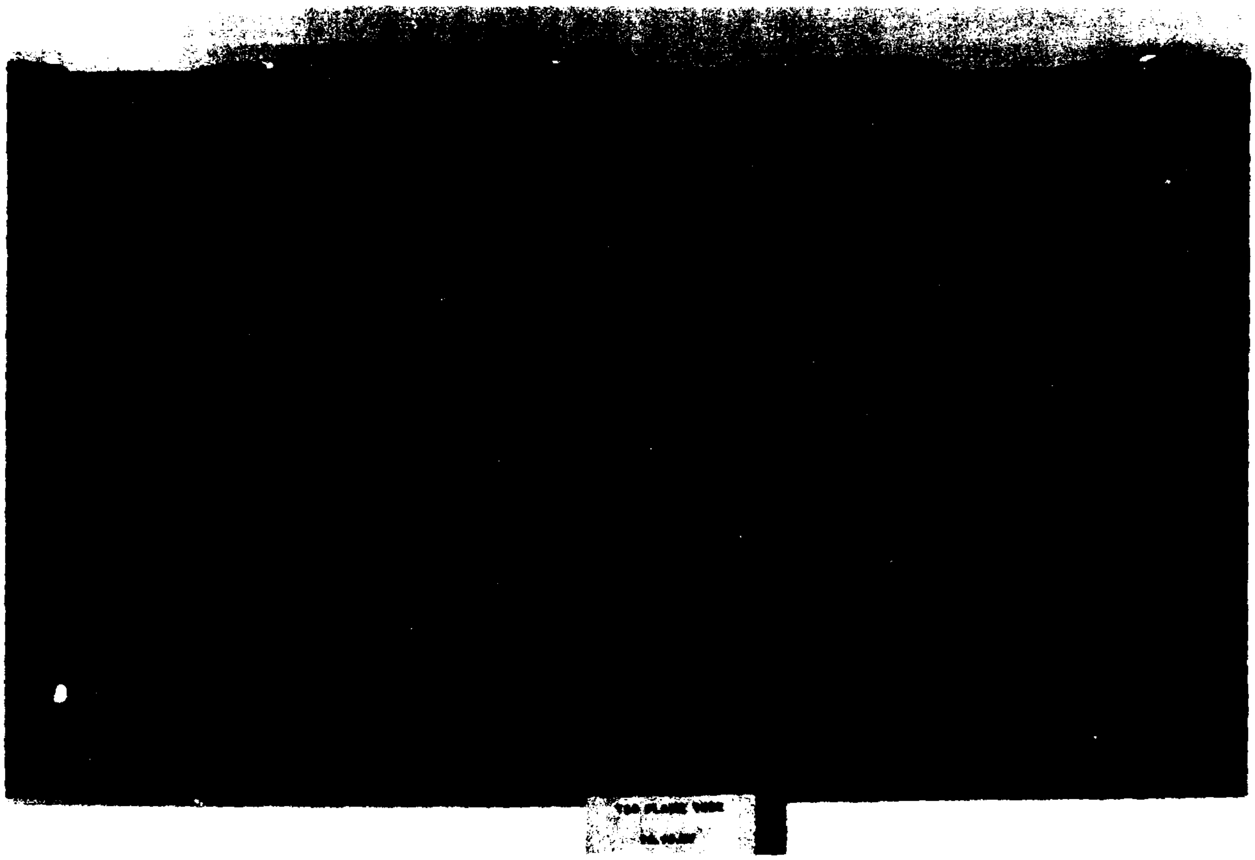

FIG. 6. FLAT PLANE PHOTOGRAPH OF THE ENTIRE CIRCUMFERENCE OF THE FLAME TUBE

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